

# Two new intertidal balanoid Barnacles from eastern Australia

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Two species of balanomorph barnacles are described from harbours and estuaries of New South Wales where they are locally very abundant intertidally. *Elminius covertus* sp. nov., is closely related to *E. modestus* from New Zealand, and less so to *Elminius kingii* from South America, and has long been mistaken for *Elminius modestus* which is now known reliably only in Australia from some ports. *Hexaminus popeiana* gen. nov. and sp. nov. is superficially similar to *Elminius* spp. but has 6 parietal plates. Both species are assigned to the Elmininae, a new subfamily in the Archaeobalanidae.

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## INTRODUCTION

*Elminius modestus* Darwin has become a well-known barnacle since its introduction and spread in Europe (see full literature citation in Newman and Ross, 1976). It has been assumed that the species was carried to Britain on ships in the 1930-40 period from Australia and New Zealand (Bishop, 1947).

In New Zealand *E. modestus* is very common in harbours and estuaries where it occurs on a wide variety of substrata in the midlittoral and shallow sublittoral zones (Moore, 1944; Morton and Miller, 1968; Foster, 1978). It is the commonest fouling barnacle in New Zealand harbours.

For Australia, the literature on *E. modestus* is perplexing to one used to the species on New Zealand (and European) shores. The early records of Darwin (1854), and the later account of Pope (1945) for Sydney shores, seem to be the basis for the Australian presence and identity of the species. For Port Jackson, Pope (1945) reported that *E. modestus* occurred 'only towards the upper limit of the tidal range which prevents it from becoming much of a nuisance on ships and small craft'. This anomaly in the intertidal range, plus the lack of data on the distribution of the species away from Sydney, prompted a closer look at the sheltered-shore barnacles of New South Wales. It was concluded (Foster, 1980) that the account of Pope (1945) refers to a different species of *Elminius* which occurs along with *E. modestus* and an undescribed 6-plated balanid on harbour shores in the vicinity of Sydney. This present paper describes both new species and considers their relationships within the Balanomorphs as recently revised by Newman and Ross (1976).

The barnacles described in this paper are abundant where they occur. Samples collected and studied contain at least 10, up to 50, specimens, at various stages of development and erosion. The two species of *Elminius* are difficult to identify when the shell is extremely eroded, and close examination is required to distinguish all 3 species when they are mud encrusted.

## SYSTEMATICS

Suborder BALANOMORPHA Pilsbry, 1916

Superfamily BALANOIDEA Leach, 1817

Family ARCHAEOBALANIDAE Newman and Ross, 1976

Balanomorph barnacles with labrum thin with pronounced medial cleft; shell wall either solid or with pores of the non-balanine type, inter-laminate figures lacking or simple.

*Remarks:* The Archaeobalanidae contain 10 extant and 4 extinct genera. The solid-walled genera fall into two groups, those that associate with various sponge or coelenterate habitats (*Armatobalanus*, *Membranobalanus*, *Acasta* and *Conopea*), and those that are free-living (*Chirona*, *Solidobalanus*, *Elminius* and *Notobalanus*). The former have hooks and teeth on cirri III and IV, the latter do not; the latter are considered to be the more primitive. The various forms of tubiferous parietes as seen in *Semibalanus* and the extinct *Archaeobalanus* and *Actinobalanus* are considered to be independent developments from the much more prevalent parietal pore condition of the Balanidae (Newman and Ross, 1976).

I have argued before (Foster, 1978, p. 130), that the calcareous base of balanomorph barnacles has been variously evolved in different groups, and that the primitive condition is a membranous base. Three of the archaeobalanid genera have membranous bases: *Semibalanus*, *Membranobalanus* and *Elminius*. *Elminius* is the only 4-plated genus in the archaeobalanids, but its simple cirri, its membranous base, and the non-interlocking radii indicate a basic origin for *Elminius*. The new 6-plated form described below also has simple cirri and a membranous base, and this combination of characters denies its inclusion in any of the aforementioned genera. It also has non-interlocking radii and seems closely allied to *Elminius*. Rather than amend the diagnoses of *Elminius* or of *Chirona* (which has a calcareous base) a new genus is proposed for this undescribed species. Furthermore, this species, and those of *Elminius*, seem to constitute a southern hemisphere subfamily as well defined as the

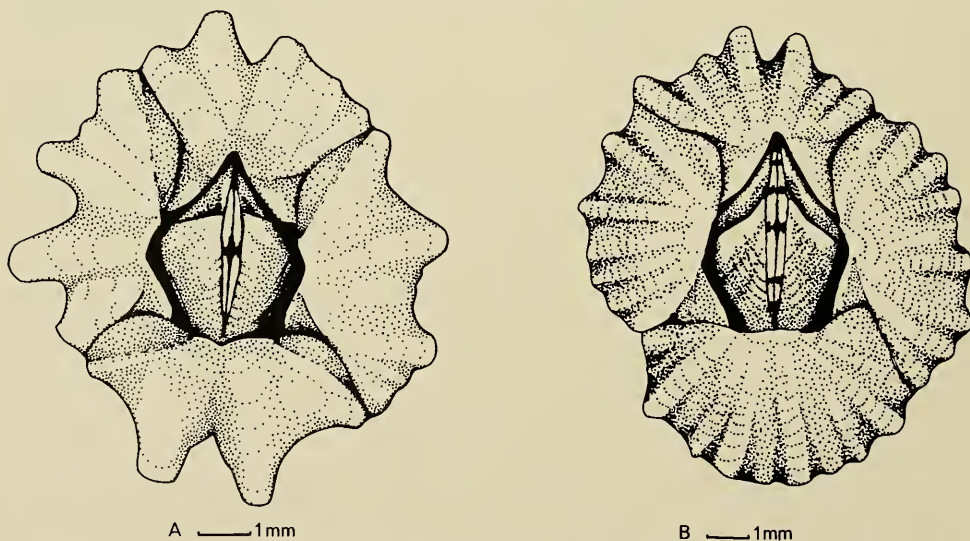


Fig. 1. A: *Elminius modestus* Darwin, drawn from a New Zealand specimen; B: *Elminius covertus* n. sp., drawn from a specimen from Swansea, Lake Macquarie.

northern hemisphere Semibalaninae. I propose the name Elmininae for this subfamily.

Genus *Elminius* Leach, 1825

Balanoid barnacles with a medially cleft labrum; 4 thin, solid parietes, radii simple, base membranous; cirri III and IV without hooks or teeth; basi-dorsal point of penis absent.

Type species *Elminius kingii* Gray, 1831 (subsequent designation, Pilsbry 1916).

*Remarks:* *Elminius* includes 3 extant species: *E. kingii* from southern South America, *E. modestus* from New Zealand, Australia and Europe, and the new species described below. The identity of *E. cristallinus* Gruvel from the Azores needs confirmation; it might be a case of introduced *E. modestus* (Newman and Ross, 1976) or the young 4-plated stage of some other species. The subspecies *E. modestus molluscorum* Kolosvary from Auckland, and *E. modestus laevis* Nilsson-Cantell from Melbourne are just two of the forms assumed by this species when growing on various intertidal substrata (Moore, 1944).

*Elminius modestus* Darwin

Figs 1A, 2

Synonymy: *Elminius modestus* Darwin, 1854:350; Guiler, 1952:20; Pope, 1966:181; Foster, 1978:95 (see for New Zealand references); Newman and Ross, 1976:52 (in part, viz. the European and New Zealand references); Foster, 1980: figs 2, 3. Not Pope, 1945:368; Underwood, 1977:23, ?17.

*Elminius modestus molluscorum* Kolosvary, 1942:147

*Elminius modestus laevis* Nilsson-Cantell, 1925:49

Australian material examined. Personal collection: Port Jackson (The Spit), 1978; Melbourne (coll. J. S. Buckeridge, 1976); Adelaide (coll. A. Gackle, 1979). Could not be relocated in Port Jackson in 1980. Australian Museum: P21284 (Newport Power House, Victoria, 1950), P21287 (Derwent River, Tasmania, 1950), P21288 (Sandy Bay, Hobart, Tasmania, 1951), P21291 (Port Lincoln, South Australia, 1951), P23569 (Port Phillip, Melbourne, boat fouling 1950), P23571 (Port Jackson, Sydney, ship fouling, 1954). There are numerous lots of specimens that have been classified under *E. modestus* but are referable to *E. covertus* (below). Description as given by Moore (1944) and Foster (1978).

Designation of lectotype: British Museum (Natural History), one of several specimens attached to an intertidal limpet *Cellana ornata* (Dillwyn), Registered No. B.M. 47.1.15.39, as arrowed in Fig. 2 and now held separately, Reg. No. B.M. 1981.274. The limpet shell is one of four shells on a wooden slab bearing on reverse a label in Darwin's handwriting. These shells are endemic to New Zealand, and despite the lack of collecting data it is assumed that the *Elminius* specimens are part of Darwin's syntype material and originated from New Zealand. Specimens of the barnacle *Chamaesipho columna* (Spengler) are included on two of the limpet shells. This association of barnacles and limpets is common on New Zealand harbour shores.

*Remarks:* Darwin (1854, p. 348) stated 'at Sydney I found *E. modestus* adhering to oysters in a muddy lagoon, almost separated from the sea, and apparently very unfavourable for cirripedes'. The question arises whether Darwin found specimens of the other species of *Elminius* described below, and whether he confounded the two species in his description of *E. modestus*. Specimens now in the British Museum, some with labels identifying them as *E. modestus* in Darwin's handwriting, are indeed *E. modestus* as known in New Zealand and as has been introduced into Europe. It is



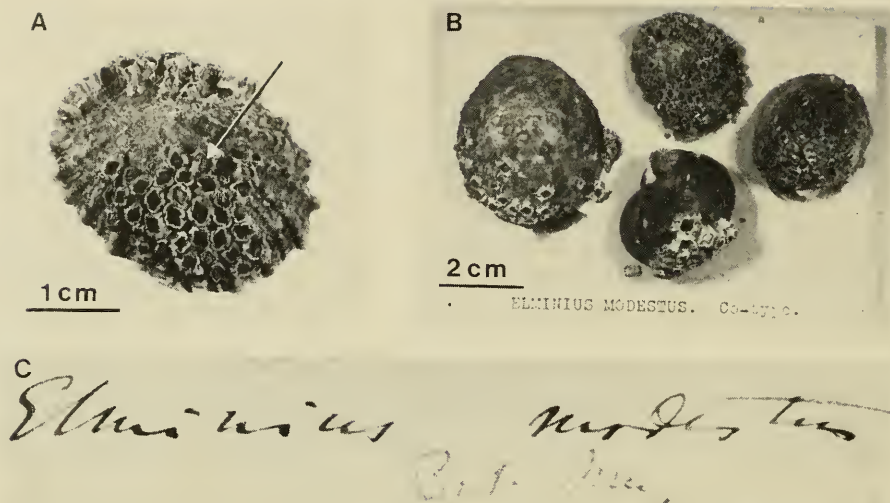


Fig. 2. *Elminius modestus* Darwin. A: lectotype arrowed, on shell of *Cellana ornata* (Dillwyn). B: lectotype and syntypes on New Zealand gastropod shells — *Cellana radians* (Gmelin), left, *Turbo smaragda* Gmelin, bottom, and *Cellana ornata* (Dillwyn), top and right. C: Darwin's own label as applied to reverse of slab pictured in B. Depository: British Museum (Natural History), London.

suspected not all Darwin's material is now in the British Museum, and there is doubt (Foster, 1980) about the labelling and the localities of some specimens he had to study. Nor are his Sydney specimens identifiable, if indeed he collected them. Darwin did not designate types and it seems purely academic to seek out all remnants of Darwin's barnacles in the possibility that some may not be *E. modestus*.

Insofar as it goes, Darwin's description of *E. modestus* does describe *E. modestus* as it is known in New Zealand and Europe. The barnacles Darwin 'found' at Sydney were on oysters, and on Sydney shores oysters are 'zoned' below the confounding species. Therefore, it is possible that Darwin did collect *E. modestus* at Sydney in 1836. More discerning collecting and identification of *Elminius* is required to ascertain the details of the geographic distribution of both species in Australia. If it is found to be restricted to major shipping ports, and absent from the intervening estuaries on the coast, then it is possible that ship-aided dispersal to Australia has occurred, some at least pre-1836.

Without examination of specimens, it is not possible to determine the true identity of the barnacles listed by Guiler (1952) and Pope (1966), and figured by Underwood (1977).

*Elminius covertus* n.sp.

Figs 1B, 3, 4A-C

Synonymy: *Elminius modestus* Pope, 1945:368; Underwood, 1977:23, ?17;  
Guiler, 1952:20; Pope, 1966:181  
*Elminius* sp. Foster, 1980:614 (figs 1, 3, 4)

Material examined. Personal collection: in 1975, Pittwater and Port Jackson; in 1978, Coffs Harbour, Nambucca River (Macksville), Hastings River (Settlement Point, Port Macquarie), Camden Haven, Wallis Lake (Tuncurry), Port Stephens (Tea Gardens, Nelson Bay), Port Hunter (Stockton), Lake Macquarie (Swansea), Broken Bay (Gosford, Bobbin Head, Pittwater), Port Jackson (Vaucluse, The Spit, Bantry

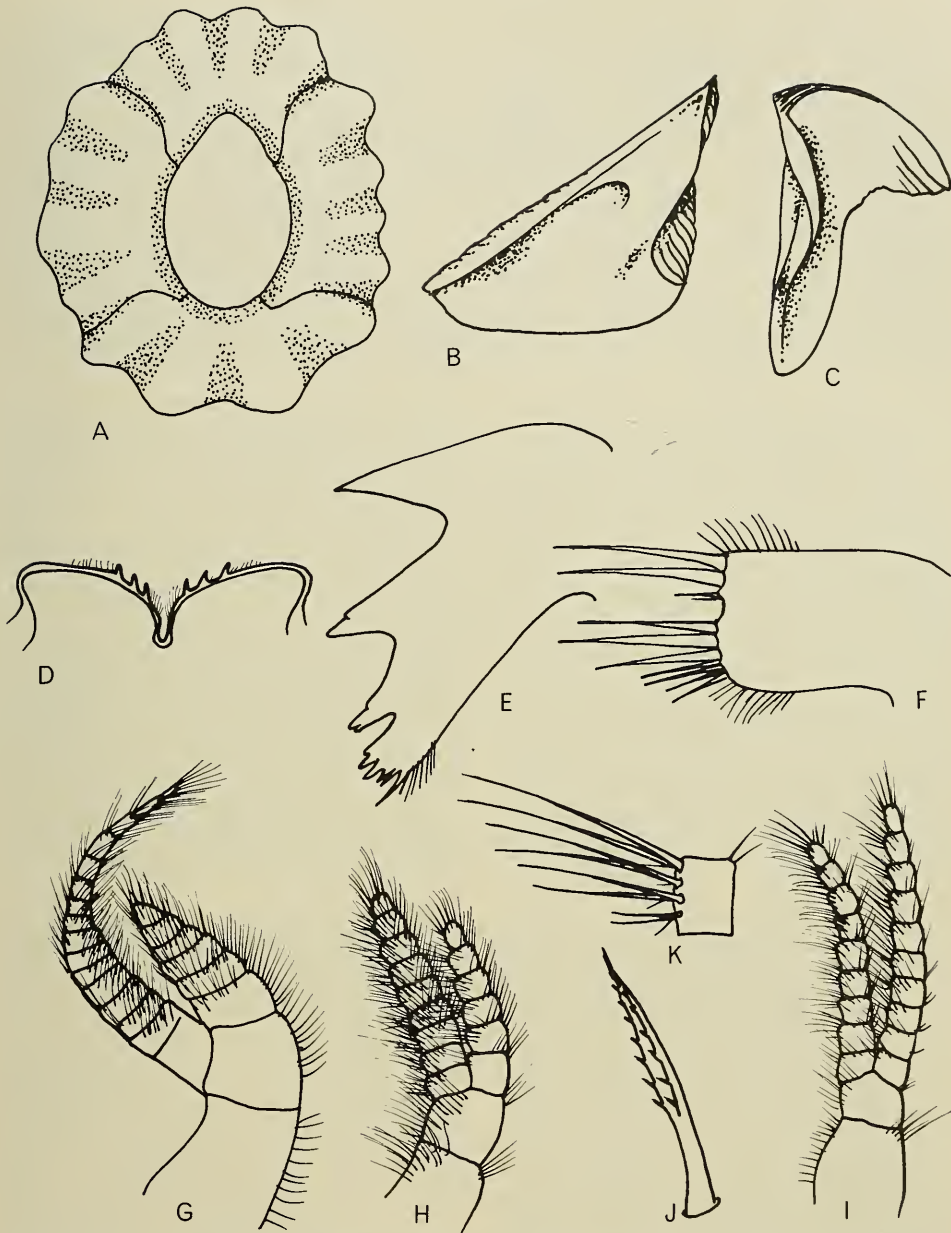


Fig. 3. *Elminius coertus*. A: inner view of shell; B: scutum; C: tergum; D: labrum; E: mandible; F: maxillule; G-I: cirri I-III; J: seta from 5th segment, posterior ramus, cirrus III; K: middle segment, posterior ramus, cirrus VI. All drawn from a 9 mm rostrocarinal diameter specimen.

Bay, Roseville Bridge), Botany Bay (Captain Cook Bridge), Port Hacking (Cronulla); in 1979, Port Jackson (Rose Bay, coll. M. F. Barker); in 1980, Pittwater and Bennelong Point.

Australian Museum: Queensland localities, P21306, P21313 (both Stradbroke Island, 1961); New South Wales localities, P21296 (Hawkesbury, 1967), P21314

(Pittwater, 1962), P21301 (Port Jackson, 1953), P21303 (Port Hacking, 1952); Victorian localities, P11643 (Kangaroo Island, Bass Strait, 1945), P21283 (Fisher Island, Bass Strait, 1930), P21297 (Mallacoota Inlet, 1957), P21309 (Westernport Bay, 1962); Tasmanian localities, P21286 (Recherche Bay, 1953), P21288 (Sandy Bay, Hobart, 1951), P21289 (Port Arthur, 1951), P21290 (Triabunna, 1951), P21295 (Port Arthur, 1951); South Australian localities, P21294 (Port Adelaide, 1950); Western Australian localities, P21311 (Bunbury Jetty, 1959), P21316 (Oyster Bay, Albany, 1959).

*Deposition of types*: Type specimens from Lake Macquarie (Swansea), coll. 8 March 1978. Holotype; Australian Museum Cat. No. P30976. Paratypes; Australian Museum, Sydney (Cat. No. P30977), National Museum, Wellington (Cat. No. Cr2238), British Museum (Natural History), London (Cat. No. 1980. 305-314), U.S. National Museum, Washington (Cat. No. 181718).

*Description*: Shell (Figs 1B, 3A): flat, with 4 parietal plates, up to 15 mm across and 4 mm high. Parietes thin, solid; basal margin sinuous from within. In uneroded specimens, parietes have pale narrow ribs alternating with pale wine-red coloured spaces between: 4 or 5 ribs per plate in young specimens but up to 9 in larger specimens. In eroded specimens, the shell is grey and granulate apically, but usually with some evidence peripherally of dark reddish-purple laminae and ribbing.

Radii narrow, not completely covering underlying alae in uneroded specimens, dark wine-red in colour, not interlocking with adjacent parietes. On erosion, the sutures between parietes remain obvious but the radii and alae are indistinguishable. Base membranous. Orifice pentagonal in outline, elongate in the rostrocarinal axis with a very short rostral side.

Opercula (Figs 3B, C): Scutum about as long or longer than high, the articular ridge occupying half articular margin and curving into the articular furrow. Internally there is no adductor ridge, nor crests for depressor muscles, but a faint adductor muscle scar. Tergum elongated with a very wide articular furrow; articular ridge standing at right angles to the pitted innerface of the plate, curving directly to a spur that merges with the basiscutal angle; basal margin concave, with 4 or 5 crests depending at the carinal end.

Externally in live, uneroded specimens, the scuta are dark red with a conspicuous widening white band along the tergal margin of each scutum; opercular membranes are white with 6 pairs of dark spots as shown in Fig. 1B.

Mouthparts (Figs 3D-F): Labrum with 3 teeth on each side of central cleft. Mandible with 5 teeth, the 2nd about  $\frac{1}{2}$  along the cutting edge from the upper tooth, the 5th merging with a pectinate lower angle which bears a prominent curved spine at the bottom point. Maxillule with a wide but shallow notch below the upper pair of spines, the main cutting edge not protuberant bearing 3 or 4 major spines and a clump of short ones at the lower angle.

Cirri (Figs 3G-K): Number of segments in the rami of 5 specimens as follows, anterior ramus first:

Shell length (mm)	I	II	III	IV	V	VI
8.5	11.6	7.6	10.9	16.17	16.18	20.19
5.2 (eroded)	12.6	9.7	11.10	15.17	23.21	25.23
12.0	14.6	9.7	11.10	17.20	24.19	21.19
12.6	16.6	9.8	12.11	18.19	22.24	25.26
9.2 (eroded)	16.7	9.8	12.10	23.21	26.27	27.27

Cirrus I with anterior ramus  $\frac{1}{2}$  as long again as posterior ramus, distal segments elongate with long setae; posterior ramus with segments slightly protuberant



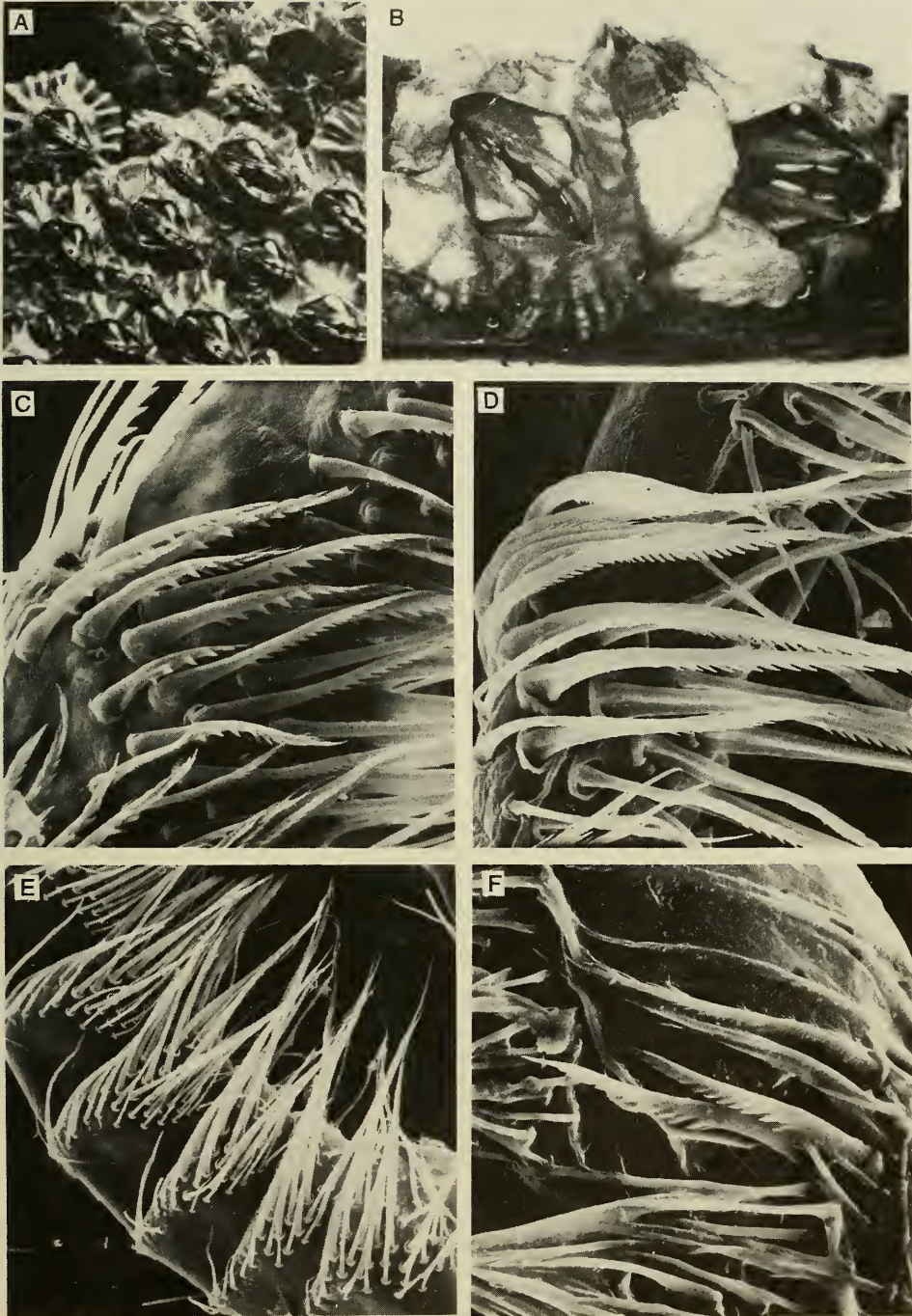


Fig. 4. A: *Elminius covertus*, group of specimens from Pittwater, photographed alive,  $\times 0.9$ ; B: *E. covertus* left and centre, *Hexaminus popeiana* right, from Swansea, Lake Macquarie, photographed alive,  $\times 2.5$ ; C-F: medial face of middle segments of posterior ramus of cirrus III of *E. covertus* ( $\times 220$ ) C, *H. popeiana* ( $\times 125$ ) D, *Elminius modestus* ( $\times 60$ ) E, *Elminius kingii* ( $\times 220$ ) F.

anteriorly. Cirrus II with anterior ramus slightly longer than posterior ramus, segments of both rami setose and slightly protuberant anteriorly. Cirrus III with subequal rami, all but basal 1 or 2 segments on medial face of posterior ramus with pectinate setae (Fig. 4C). These pectinate setae are much stouter than the finely feathered setae of the posterior rami. Cirri IV to VI with square segments with 4, rarely 5, pairs of setae on the anterior edge. Penis  $1 \times$  length of cirrus VI, no basal dorsal point or setae.

Etymology: with reference to the species being so long unnoticed on harbour shores.

*Remarks:* As both *E. modestus* and *E. covertus* may occur together it is desirable to emphasize the distinguishing characters. In young uneroded shells the reddish to buff colour of *E. covertus* is in marked contrast to the vivid white shell of *E. modestus*. Also, the narrow contrastingly-coloured ribs of *E. covertus* differ from the uniformly white and broadly-folded parietes of *E. modestus*.

Eroded shells are harder to identify; close inspection may reveal a stellate basal margin where 'the continuation of the ribs stick out round the margin in a series of points' (Pope, 1945:369).

As with all intertidal barnacles, there is some variation in the dimensions of the scutum, ranging from almost isosceles (with articular and basal margins equal) to the basal margin being  $1\frac{1}{2}$  times the length of the articular margin, perhaps a feature of flat conic species growing on different substratum contours.

The terga also vary in shape mostly due to the degree of erosion of the outer face. The terga of *E. covertus* are more elongate than those of *E. modestus* ('hatchet-shaped' of Pope, 1945), with the articular ridge overhanging the spur with which it merges (forming the 'handle of the hatchet') and extending as a thickened rim around the apico-carinal region. The triangular region between the depressor muscle crests and the spur is notably thinner, often pitted. In *E. modestus* the inner surface slopes to the apex and articular ridge, and is roughened in larger specimens.

The major point of difference in the appendages is the presence of pectinate setae on the posterior ramus of cirrus III in *E. covertus* (Fig. 4C), absent in *E. modestus* (Fig. 4E).

In the gaping animals, the tergoscuteal flaps reveal the most marked distinguishing character. In *E. covertus* (see Fig. 4A, B; Fig. 1B) they are white with 6 pairs of discrete black spots, one at the groove, 3 to the carinal side and 2 to the rostral side.

On the basis of the opercula, *Elminius covertus* and *E. modestus* are more closely related to each other than to *E. kingii* of South America; in *E. kingii* the tergal spur is separate from the basiscuteal angle and aligned with the articular margin as it is in *Solidobalanus* spp. However, the posterior ramus of cirrus III of *E. kingii* bears pectinate setae (Fig. 4F) like those in *E. covertus* (Fig. 4D), lacking in *E. modestus* (Fig. 4E).

#### Genus *Hexaminius* nov.

Balanoid barnacles with a medially cleft labrum; 6 thin, solid parietes; rostrum not elongated; radii simple; base membranous; cirri III and IV without hooks or teeth; basi-dorsal point of penis vestigial.

*Remarks:* This is a monospecific genus proposed to accommodate the species described below, hereby designated the type species.

*Hexaminius popeiana* n.sp.

Figs 4B, 4D, 5, 6

Synonymy: *Solidobalanus* sp. Foster, 1980: p, 614, fig. 3

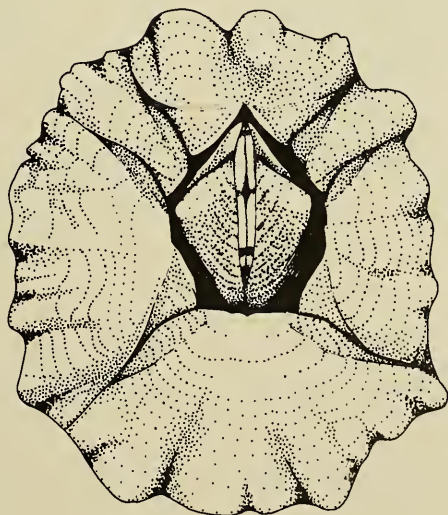


Material examined. Personal collection: New South Wales localities: In 1975, Careel Bay; in 1978, Hastings River (Settlement Point, Port Macquarie), Wallis Lake (Tuncurry), Port Stephens (Tea Gardens, Karuah, Nelson Bay); Lake Macquarie (Swansea); Broken Bay (Gosford, Careel Bay, Bobbin Head); Port Jackson (The Spit, Roseville Bridge, Vacluse); Botany Bay (Captain Cook Bridge); Port Hacking (Cronulla). Further specimens from Rose Bay (Port Jackson) in 1979, (coll. M. F. Barker); in 1980, Pittwater (Broken Bay) and Bennelong Point, Port Jackson.

Deposition of types: Holotype and paratypes — Australian Museum, Sydney, Cat. No. P30974 (holotype) Cat. No. P30975 (paratypes) from Lake Macquarie, 8 March 1978. Paratypes — National Museum, Wellington (Cat. No. Cr2239), from Cowan Creek, Hawkesbury, coll. 9 March 1978; British Museum (Natural History), London (Cat. No. 1980.315-320), from Lake Macquarie, coll. 8 March 1978; U.S. National Museum (Cat. No. 181719), Cowan Creek, Hawkesbury, coll. 9 March 1978.

*Description*: Shell (Figs 5, 6A): conic, up to 10 mm across and 4 mm high. Rostrum wide; carinolatera about 1/3 width of latera. Compartments solid throughout, thin, sometimes broadly sinuous, without ribs internally, with basal edge truncated. Raddi narrow, with simple edges, not interlocking with adjacent parietes, exposing much of the underlying ala. In young and uneroded specimens, shell compartments with broad pale bands alternating with bands of purplish to wine red colour, the latter with white flecks which underly short projecting spines that line the growth ridges. In eroded specimens, colour generally white with narrow darker stripes confined to the depressions between the broad 'ribs'. Base membranous. Orifice pentagonal in outline, with a very short rostral side.

Opercula (Figs 6B, C): Scutum longer than high, articular ridge occupying 2/3 articular margin, with deep articular furrow; internally with very faint muscle attachment scars, and a weak adductor ridge. Tergum waisted by having a concave basal margin, but straight articular margin; deep articular furrow; spur close to but separate from the basiscutal angle, forming an acute angle with the short part of the



— 1mm

Fig. 5. *Hexaminus popeiana* n.gen. and n. sp., drawn from a specimen from Rose Bay, Port Jackson.

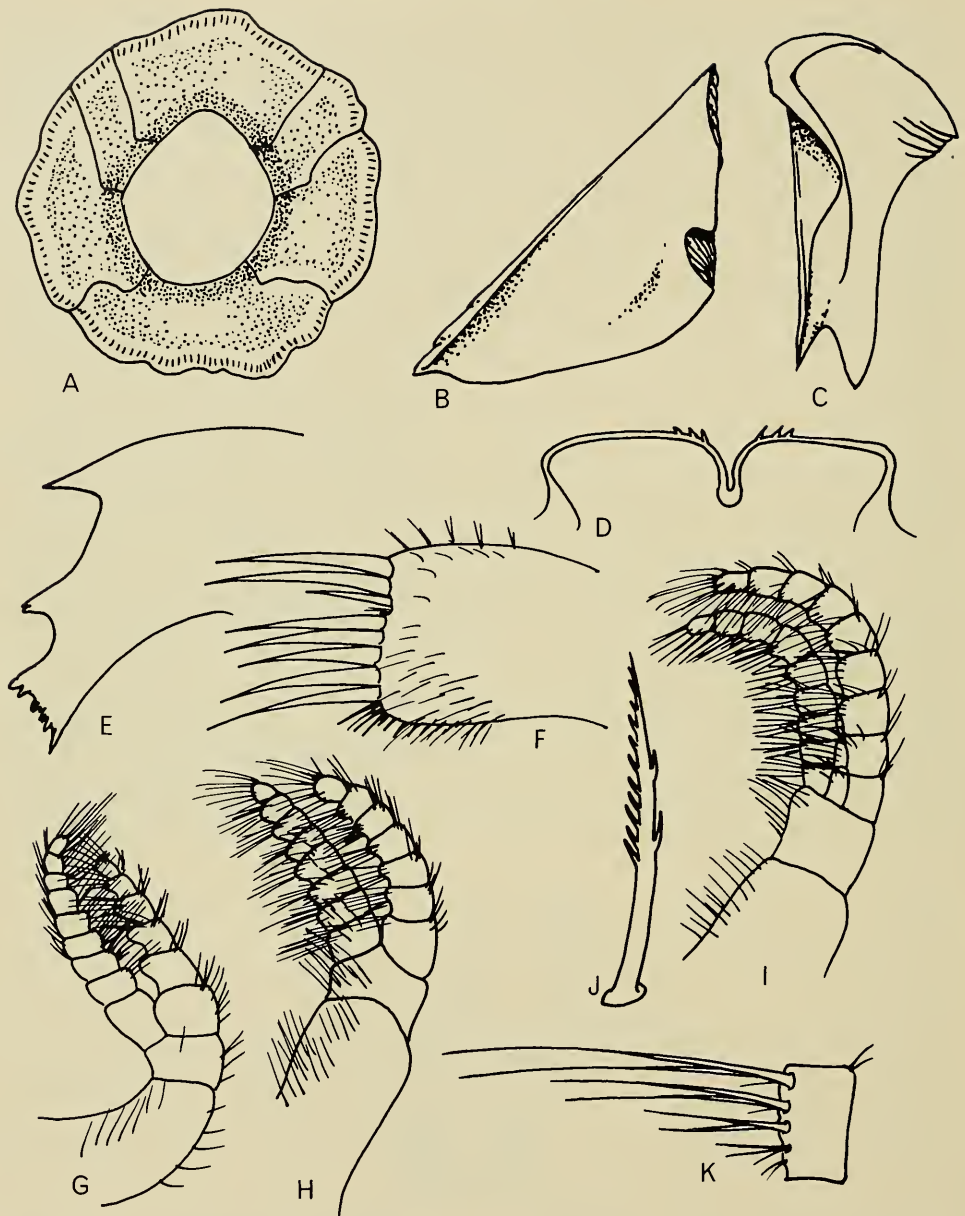


Fig. 6. *Hexaminus popeiana*. A: inner view of shell; B: scutum; C: tergum; D: labrum; E: mandible; F: maxillule; G-I: cirri I-III; J: seta from 7th segment, posterior ramus, cirrus III; K: middle segment, posterior ramus, cirrus VI. All drawn from a 9 mm rostrocarinal diameter specimen.

basal margin on that side, spur curves gradually to the concave basal margin, which on the carinal side is prominent with 4 or 5 crests for the carinal depressor muscles. Externally in live specimens, the scuta are dark purple red with an inconspicuous pale flange along the tergal articular edge of each scutum; opercular membranes off-white with paired markings as shown in Fig. 6C.

Mouthparts (Figs 6D-F) : Labrum cleft, with 3 teeth on either side. Mandible with 5 teeth, the uppermost separated from the 2nd by half the length of the cutting edge; the 3rd, 4th and 5th merging into a molariform lower angle which may bear a few short spines. Maxillule with a slight notch below the upper pair of spines, the edge below not protuberant, with 5 or 6 spines, the lowest 2 of which equal in length the 2 above the notch.

Cirri (Figs 6G-K) : The numbers of segments in the rami of cirri of 3 specimens as follows, anterior ramus first :

Shell length	I	II	III	IV	V	VI
4.8 mm	9,6	8,7	9,9	16,17	20,20	21,20
9.6 mm	14,7	8,8	10,10	20,21	24,24	25,25
9.6 mm	13,7	8,9	11,10	21,20	24,24	26,26

Cirrus I with anterior ramus only slightly longer than posterior ramus. Cirrus II with subequal rami. Cirrus III with subequal rami, setae on distal 3 or 4 segments of both rami serrated more on one side than the other (Fig. 4D and Fig. 6J). Basal segment of cirri III very broad. Cirri IV to VI with segments slightly longer than wide, each with 5 pairs of setae on the anterior edge. Penis longer than cirrus VI, with a small basal dorsal point bearing 2 setae, and with a prominent pedicle.

Etymology: named in honour of Miss Elizabeth Pope, student of Australian barnacles, whose collections in the Australian Museum contain numerous lots of this species. It is a species she has clearly pondered on.

*Remarks* : The poreless shell structure and unmodified 3rd and 4th cirri indicate an affinity with *Notobalanus* and *Chirona*; the position of the tergal spur, set aligned to the articular margin and very near to the basiscutal angle, resembles *Solidobalanus* and *Elminius kingii*. The absence of a calcareous base precludes its inclusion in any of these genera. Nor can it be included in the membranous-based genera *Semibalanus* and *Membranobalanus*, because of the poreless shell and simple cirri respectively.

The similarity of *H. popeiana* with *Elminius* is striking, particularly with respect to the primitive features of non-toothed cirri, basiscutal position of tergal spur, the membranous base, and the non-interlocking radii. Indeed, *Hexaminus* satisfies the requirements of an *Elminius* ancestor as discussed by Foster (1978, p. 97).

All species of *Elminius* and *Hexaminus* are characteristic of shallow sea habitats and estuaries. Their weakly-constructed shells are inappropriate to surf habitats. These species, the Elmininae, may represent the survivors of an early stage in balanid radiation before the development of stronger radially-interlocked shells like those of *Solidobalanus*. They perhaps indicate a southern hemisphere development to parallel the Semibalaninae (e.g. *Semibalanus balanoides*) of the northern hemisphere. The fouling proclivity of *E. modestus* has enabled it to overcome oceanic barriers and become sympatric with related species in Australia and Europe.

#### ACKNOWLEDGEMENTS

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